Rethink the target: drivers, barriers and path dependencies for a low-carbon-transition in shrinking cities – the case of Oberhausen

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Abstract
The role of cities in mitigating GHG emissions and thus tackling global warming has gained importance over the last years. Many cities have developed climate action plans, primarily to achieve long-term "low-carbon" mitigation goals set by national governments or (inter)national agreements. A mere adoption of high level targets, however, raises the question whether these targets are applicable for cities with very different framework conditions.

We argue that it is crucial to understand the socio-economic, geophysical, spatial, infrastructural and political framework of a city – a broad approach, which is generally missing in climate action plans. Thus, determining drivers and barriers for future development paths is neglected by local policies, which leads to a gap between ambition (target) and reality (implementation).

We exemplarily examine this hypothesis for the shrinking city of Oberhausen (Germany). Oberhausen, located in the Ruhr area, is a typical old industrial region, which has seen a decline of its industrial basis over the last decades. We analysed historical data and developed scenarios until 2030. Both show a significant decrease in CO_2 emissions. A closer look, however, reveals that the reduction is primarily due to the economic transformation (less manufacturing, more service industry, accompanied by a decrease in population) and general energy efficiency developments following the implementation of national and EU policies. Although the city has implemented – and will further implement – many instruments and policies to reduce CO_2 emissions, local barriers such as unemployment, low rents, low income, high per capita debts, etc. dramatically reduce the city's capacity for action.

The results show that Oberhausen's emission reductions do not reflect active energy policies but are mainly driven by an economic decline. To reach ambitious reduction targets, however, the city needs to be enabled to take action in achieving appropriate and reasonable targets.

Introduction
With the growing global effort to mitigate climate change, different approaches have evolved over the last two decades to lower energy demand and transform fossil fuel based energy systems into sustainable and low-carbon systems. In addition to international organisations, national governments and single companies, cities – as institutions in a multi-level governance framework that are closest to residents and companies – start to play a growing role in combatting climate change. Globally, cities are responsible for 71 percent of the energy-related GHG emissions and this figure is expected to rise in the next decades (IEA and OECD, 2008).

Many local governments have recognized their responsibility and have committed to ambitious GHG emissions reduction targets, either through their membership in city networks like C40 Cities, Local Governance for Sustainability (ICLEI), the Covenant of Mayors (CoM) or the Climate Alliance, or by setting their own targets. They are doing so not only because of their responsibility to future generations or their vulnerability to climate change impacts but also because of possible economic benefits that accompany climate protection engagement. Another motivation factor is the enhancement of their residents' quality of life. However, the set targets often neglect the specific framework of a city in mitigating GHG emissions, which may lead to unsuitable actions and thus may undermine the credibility of local decision-making.

The city of Oberhausen is a member of the Climate Alliance network and thereby committed to halve its GHG emissions by 2030 (compared to 1990) and strives for a low-carbon transition – a significant emissions reduction of 80 to 95 percent – in the long run. With the development of a Climate Action Plan in 2011/12, possible development paths until 2030 have been outlined. The aim of this paper is to analyse the emission path of the city beginning in 1990, to highlight main factors that have driven and will drive urban emissions and to try to assess Oberhausen's reduction target according to its feasibility and appropriateness. Therefore, we will first describe which dimensions influence a city's ability to act on GHG emissions reduction in general, then exemplify those factors for the city of Oberhausen and finally summarize lessons learned about defining more locally adjusted reduction targets.

Low-Carbon transition – is a target sufficient to meet the challenge?

Many cities around the world have recognized their responsibility associated with global warming. They have committed to CO_2 reduction targets and have developed climate action plans accordingly[1]. With regard to their long-term mitigation goals, cities in OECD countries primarily follow the recommendation made by the IPCC – a GHG-emission reduction of 80 to 95 percent by 2050 compared to 1990 to stay within the 2 °C guardrail – or they follow national targets as well as targets set by city networks (Solomon, 2007; Sippel, 2011).

The use of this long-term target contains three main fallacies. First, from a physical point of view, global warming does not depend on the emissions level in 2050. It rather depends on the amount of emissions released until that point of time. The so called "budget approach" offers a new perspective on required emission reductions. Recently, the German Advisory Council on Global Change (WBGU) published its findings associated with this approach for several countries. According to the scenario "future responsibility" the world's carbon budget (based on fossil CO_2-emissions, i.e. without land-use change) will be reached in 25 years, which means that global net emissions should be zero after 2035. Countries like the USA, Germany or China will reach their budget limits in 6, 10 or 24 years respectively (WBGU 2009). Second, long-term reduction targets are mostly an average, e.g. the reduction of 80 to 95 percent as recommended by the IPCC has to be achieved by the OECD country group, which implies that some countries have to achieve a higher emissions reduction than others according to their demographic, ecological and economic frameworks. Third, the measurement of urban GHG emissions is mainly based on the same methodology used for countries. This means that emissions within the geographic boundaries of a city are taken into account. However, with the world becoming more and more globalised, production-based GHG inventories may be misleading (Schulz, 2010; UN-Habitat, 2011). A consumption-based inventory in addition to the "traditional" inventory is crucial for a sufficient understanding of the emissions caused by urban activities – despite the problems related to this approach due to a much higher complexity of the emissions measurement and accounting (Peters, 2008).

If it is hardly possible to transfer the global reduction target to country level due to the above mentioned problems, the adoption by a city is even more questionable and in many cases it is unsuitable to the existing urban framework. However, this is the reality for many cities around the world. According to the annual report of the carbon*n* Cities Climate Registry (cCCR), 75 percent of the communities studied have committed to a GHG reduction of more than 1 percent per year, which exceeds the commitment of most national governments under the Kyoto Protocol (Arikan, 2011). An analysis of German cities shows similar results. Almost three out of four cities have adopted targets that were not derived from an analysis of mitigation potentials, and thus are not city specific and neglect existing urban drivers and barriers (Sippel, 2011).

We now have a situation where there is a high local commitment to mitigate CO_2 emissions and to protect the world from the negative impacts of global warming. Yet the commitment is based on cities' memberships in city networks or the adoption of (inter)national targets, rather than an assessment of the socio-economic and ecologic framework and mitigation performances of each city. The prevailing paradigm expects that a transition from the current emissions level to a low carbon level will be possible for all cities.

This simplification however is inappropriate to urban frameworks. Cities differ. There are shrinking cities that have experienced an economic downturn over the last decades and there are economically growing cities with a strong service sector and high international interdependence. Urban planning approaches differ between continents, countries and even between regions within a country. The physical location of a city entails different needs for energy use (heating, cooling etc.) and thus requires specific solutions to reduce energy use. In addition the political framework and local governments' capacities to act vary between countries.

Therefore a low-carbon transition is a multi-dimensional process and the path depends on the existing framework of a city.

Dimensions of path dependency – drivers and barriers for a low-carbon transition

GEOPHYSICAL DIMENSION

The geophysical situation cannot be influenced by a city. Nevertheless the altitude, the location of a city in relation to natural resources etc. have an impact on its energy demand, the potential of renewable energy use, and thus characterize the low carbon transition path and opportunities of a city.

Climate conditions affect the energy demand for heating and cooling. Urban areas in high latitude locations have a lower mean temperature and longer hours of darkness, so they require more energy for heating and lighting (Glaeser, 2010). In contrast, cities in warmer locations have a higher energy demand for space cooling through air conditioning (Valor et al., 2001).

1. Lists of existing climate action and energy action plans can for example be found on the following websites: http://www.climateactionplans.com/energy-climate-action-sustainability-plans/; http://www.eumayors.eu/actions/sustainable-energy-action-plans_en.html.

The location of a city also affects the kind of sources used for energy generation. Cities with nearby coal mining rely more on coal as an energy source than cities in proximity to natural gas fields. The city of Prague uses less energy per capita for heating than New York, but since the energy system primarily relies on coal, its per capita emissions are higher than those of New York (Kennedy et al., 2009). On the other hand, there is also the opportunity that cities are located next to energy infrastructures (e.g. gas pipelines) and rely on the transmitted energy carrier although there are no local resources. In terms of renewable energies, the location of urban areas determines their potential use[2].

SPATIAL DIMENSION

Urban development models vary through time and by region/ country/continent. They impact the urban phenomenology, and thus influence the mobility behaviour of the residents, the built environment and infrastructure. In general, a historical transition from walkable cities via transit cities (dense urban centres spreading along rail line corridors) to automobile cities (sprawling outwards and having low density) has been observed globally (Newman, 2009).

Today, cities in Southeast Asia are four times as densely populated as European cities and almost eight times as densely populated as those in North America and Australasia (UN-Habitat, 2011). However, the general trend from higher to lower density is evident in cities in developed and developing countries alike (Angel et al., 2005).

Urban density affects the energy use and per capita GHG emissions of a city in three main ways: by (1) mobility patterns and behaviour of residents and local companies, (2) energy use for heating and cooling from buildings and (3) efficiency of energy systems like district heating or local heating networks. Research has shown that urban density influences travel demand (Newman and Kenworthy, 2006). The denser a city the higher the proportion of less carbon intensive activities like walking, cycling or using the public transport. A study conducted for the city of Toronto examined this correlation. It concludes that the emissions from private vehicles increase with an increasing distance from the central part of the city. In low-density parts of Toronto the energy use and GHG emissions per capita can be 2 to 2.5 times higher than in inner-city areas (Norman et al., 2006). However, density itself is not the key. It is more about the new lifestyles triggered by the increase in density and mixed-land use that reduce per capita GHG emissions. With stores, places of employment, cinemas and public spaces like parks nearby, people tend to travel less. Moreover, transport needs and therewith regional integration of single cities is higher for small cities than for bigger cities or towns, e.g. the workplace is likely further away from the place of residency. Therefore, one has to keep in mind that commuter traffic might not just be important in the case of big cities with high commuter inflows but also for smaller cities with high commuter outflows.

Urban density may also affect the energy consumption of households. Multi-family housing, with all other variables being constant, requires less energy because the ratio volume/building envelope is higher than in single-family detached housing. US households living in detached homes consume 35 percent more energy for heating and 21 percent more for cooling than comparable households in other building types (UN-Habitat, 2011).

District heating or local heating networks for cooling or heating also benefit from urban density. Distribution losses can be minimized and economic efficiency is given as the energy demand per square kilometre is higher than in low-density areas. After the oil crisis of the 1970s, several countries and cities, in particular in Scandinavia, developed district heating systems in combination with CHP (combined heat and power) to meet energy demands more efficiently and to be more resilient against price shocks and resource scarcity (IEA, 2009).

BUILT ENVIRONMENT AND INFRASTRUCTURE DIMENSION

The built environment, which includes public, residential and commercial/industrial buildings, plays a crucial role in realising a low carbon path. On a global scale the building sector is responsible for approximately 40 percent of the total final energy demand and has a share of one third in GHG emissions (IEA, 2008). To reduce both, a huge variety of energy-efficiency technologies, energy-demand reduction practices or alternative technologies for heating and cooling fuelled by renewable energies can be implemented for new and existing buildings (Moore, 2012).

So far, the imperfection of the real estate market, in particular for the rental housing stock (e.g. an imbalance of demand and supply of living units), has been neglected in the discussion about drivers and barriers for energetic refurbishment. There are two opposite effects: first, the market demand exceeds the supply, leading to high rents. Second, the supply of living and business space is greater than the demand, leading to low rents and low profit margins for property owners. Both effects serve as disincentives for energy performance investments. In Germany, several policies are in place to facilitate the energetic retrofit of the existing building stock. Yet, the rate of energetic building renovation is still below 1 percent – only half the national target (Hennicke et al., 2012). Another major barrier to enhancing the energy performance of the rental building stock is the investor-user dilemma. That means the landlord cannot (fully) pass the added refurbishment costs on to the tenant.

In terms of urban infrastructure, the existing transport and energy supply infrastructure influence the primary energy use of a city. The long-used urban planning approach focussing on car use with low mixed land use affects urban emissions in two ways. First, maintenance of roads and associated infrastructure is expensive, so fewer funds are available for more sustainable modes of transport. Second, low demand per unit of area makes public transport hardly economically efficient (Holmgren, 2013). Urban sprawl also complicates or even makes walking and cycling impossible. Mixed land use, transit-oriented development instead of further urban sprawl and enhancement of the inner city attractiveness are essential in long-term urban planning for compact city structures. However, the urban infrastructural "heritage" differs between cities of different continents, countries and even regions and thus may serve as drivers or barriers for low carbon transitions.

Energy related emissions can also be reduced by the existing energy infrastructure. Grid-bound energy systems like district

2. Coastal cities have a high potential for wind power and in some places also for tidal power, cities in lower altitude can easily benefit from the use of solar photovoltaic and solar thermal energy.

heating allow supply to the majority of the residents with only one energy system. Running a district heating system with renewable energies or shifting from natural gas to biogas, fundamentally impacts the emission level of a city. One reason for the low emission level of Copenhagen is its area-wide district heating system. 98 percent of all buildings are connected to a district heating system fuelled by waste in incinerations and CHP's. On the other hand, district heating systems require a minimum energy demand to be economic efficient and maintenance costs increase in low density areas. Another major factor is a city's control over local energy utilities: cities that have control over them[3] have lower rates of energy related emissions than cities that don't (Sippel, 2011).

SOCIAL DIMENSION

The total population of a city affects its absolute emissions. Therefore, reducing GHG emissions for a growing city is harder than for a shrinking city. However, to compare the emissions paths of different cities, population growth alone is not sufficient as the relationship between population growth and GHG emissions is more complex. Satterthwaite (2009) examined the change in emissions levels and population for different nations between 1980 and 2005. He concluded that there is hardly any relationship between rapid population growth and GHG emissions growth. In his opinion it is not population growth that drives an increase in GHG emissions. It is rather the increase of the level of consumption.

The impact of lifestyle and consumption patterns on GHG emissions is mainly dependent on the demographic composition of a society and the income of households and residents. Sanquist et al. (2012) used a multivariate statistical approach to analyse the impact of lifestyle on U.S. residential electricity consumption. According to the analysed data, lifestyle patterns reflected 42 percent of the variance in electrical consumption.

Demographic changes do not only relate to the demographic composition of a society but also to changes in household size. An analysis for Germany has shown that past improvements in the energy performance of residential buildings in Germany have not fully resulted in a decrease in absolute and per capita energy use for heating as the decline in household size and the increase in per capita living space has counteracted energy efficiency improvements (Venjakob and Hanke, 2006).

ECONOMIC STRUCTURE DIMENSION

The structure of an economy has a significant impact on energy consumption and thus GHG emissions. Some activities, like mining or the manufacturing of goods, are more energy-intensive than the provision of services. However, every economic activity leads to some energy consumption due to production, transportation, distribution, storage and disposal. An increase in GDP thus usually contributes to an increase in energy consumption and GHG emissions. For those cities that still have a high proportion of manufacturing industries, the share of GHG emissions of the industrial sector is still significant. In contrast, the service sector only contributes little to the total GHG emissions of a city. This holds particularly true for the producer-oriented approach to calculating emissions of a city. But it has to be kept in mind that emissions might just be "outsourced".

The case of the German reunification shows in an impressive way what structural changes in an economy can lead to: emission reductions due to the breakdown and restructuring of the East German industry in the 1990s are estimated to account for half of the 18 percent cut in GHG emissions in Germany in the period from 1990 to 2000 (Schleich et al., 2001). In Tokyo the share of the industrial sector's emissions has declined from 30 to 10 percent over the last three decades, although the cities' population has grown within the same time period. Many cities have transitioned into a more service-based urban economy. Cities provide services for their residents and surrounding areas and rely on manufacturing goods delivered from elsewhere in return.

CLIMATE GOVERNANCE DIMENSION

The question of integration is dominant in the discussion about climate governance because of the many steps to be taken in enforcing a successful climate change mitigation policy, e.g. the definition of long-term emission targets and specific sub-targets by a city's authorities in achieving emission reductions, the development of action plans, the implementation of local policies and measures (P&M), the enforcement of local and national P&M as well as monitoring and verification of set targets

The three sub-dimensions of city's policy integration are "on-the-spot", horizontal and vertical integration. On-the-spot integration: local authorities have jurisdiction in several fields of action e.g. urban planning, public transport, local utilities etc. However, to fully make use of the potential to reduce GHG emissions, climate change has to become a key issue within decision-making and all relevant local departments must be networked. Moreover, local climate actions need broad support from residents and stakeholders. Therefore, it is crucial that these groups are involved in the planning processes and that social and economic co-benefits from climate policy intervention are clearly communicated[4]. Horizontal integration means that cities work in close cooperation with neighbouring cities and that they are part of city networks. Both serve to enhance local expertise, facilitate best-practice transfer and help find innovative solutions (Keiner and Kim, 2007).

From a "vertical" perspective, local action is embedded in multi-level governance. Corfee-Morlot et al. (2009) distinguish between three approaches to describe multi-level governance – nationally led, city led and hybrid models. Germany for example represents the latter approach. The energy concept of the federal government from 2010 and the "Integrated Energy and Climate Program" (Integriertes Energie- und Klimaprogramm) implemented in 2007 frame Germany's action and commitment to reduce energy related emissions and foster climate protection (Hennicke et al., 2012). Within this framework, local activities are directly supported by the federal government

3. e.g. facilities are directly operated by the city or a city owned company, the city is a major shareholder or representatives of the city government are member of the supervisory board of the facility operator.

4. Moreover, because of their direct link to the local population, cities might gain importance in the discussion about the limitation of price induced and psychological rebound effects related to energy efficiency improvements (e.g. increasing living space per capita or changed individual temperature threshold leading to higher room temperatures and therewith higher energy consumption).

through a service agency for local climate mitigation actions (dissemination of information, exchange on best-practices) and indirectly by the national climate protection initiative's incentive programmes (e.g. for small CHP installations, renewable energy in heat generation). On the other hand, there are several bottom-up approaches (although German cities are not yet obligated to take action on climate change) that can serve as an example such as the "100 % Renewable Region" – a network of cities which have committed to transfer their energy system from fossil fuels to renewable energies in the long run[5].

The analysis has shown that the emission level of individual issuers in cities is dependent on several framework conditions. Of course the degree of influence of the individual dimensions can vary among cities and interdependencies occur between these dimensions. The description of internal and external factors influencing a city's climate protection efforts is not complete, but rather a first attempt to depict factors which constitute drivers and barriers for cities and greatly influence their ability to act on climate change. In the next section, the depicted drivers and barriers are illustrated using the emission development of Oberhausen between 1990 and 2030. The relationships between the individual dimensions and their influence on the sectors transport, private households, industry/service and energy generation is illustrated for this particular case.

Shrinking city Oberhausen – on the way to a low-carbon city?!

OBERHAUSEN – SHRINKING CITY WITH GROWING CHALLENGES

The city of Oberhausen is a shrinking city within the Ruhr area – the former largest industrial region in Europe. With a population of 219,000, Oberhausen is the 6th largest city in the Ruhr area. Oberhausen – like the other Ruhr area cities – has undergone dramatic economic changes in the past half-century. The former prosperous city with its economic strength in mining, steel production and processing has since lost population and its former economic basis. Today, it is Germany's city with the highest per capita debt.

Despite the existing restrictive framework, the city has committed to mitigate climate change although local authorities in Germany are not legally obligated to reduce GHG emissions. Climate-related issues are embedded in the existing regional land development and the urban development plans. The concept for bike traffic aims to improve the conditions for cycling, and public transport is supported through Bike&Ride, Park&Ride and other measures. In 2010 the city passed an "Eight-Point-Program" to facilitate and accelerate climate protection. The city is also member of the EEA (European Energy Award – a programme for planning and realising energy and climate protection policy goals and measures in cities) and received awards for its climate actions. Moreover, the city of Oberhausen is a member of the Climate Alliance network and thus commits to halve its GHG emissions by 2030 (compared to 1990) and it strives for a low-carbon transition. With the development of a Climate Action Plan in 2011/12, possible development paths until 2030 have been outlined.

5. http://www.100-ee.de/ (German).

OBERHAUSEN'S EMISSIONS PATH – A HISTORIC PERSPECTIVE

Preliminary remarks on the methodological approach

We developed a methodology to measure Oberhausen's GHG emissions in the last two decades (1990–2008). Oberhausen's GHG inventory contains emissions related to energy consumption within the city boundary. Using the terminology of the World Resources Institute/World Business Council for Sustainable Development (WRI/WBSCD) scope 1 emissions were ascertained (WRI and WBCSD, 2004). Scope 2 emissions, namely out-of-boundary emissions due to electricity use in the city, were measured too. To estimate the emissions from power generation, we used an emission factor based on the existing fleet of power plants in Germany. In regard to transport emissions, neither gasoline consumption nor vehicle kilometres travelled within the spatial boundaries of Oberhausen were available in order to get a consistent picture of the considered time period (1990–2008). We closed this gap by using a hybrid approach consisting of statistical figures (e.g. registered vehicle types) and existing mobility surveys of Oberhausen's residents. Therefore GHG emissions from transportation do not reflect in-boundary-emissions, they rather measure emissions caused by Oberhausen residents. Non-energy related emissions from industrial processes[6], emissions from waste or from agriculture were not taken into account due to missing data and limited relevance, respectively. As we only consider energy-related emissions, only CO_2 emissions (including upstream emissions) were taken into account. Other GHG are not included in the inventory. We differentiate between emissions from private households, the economy sector (divided into service sector and industry sector) and emissions from transportation. Emissions from power and heat generation are not separately shown, but allocated to the consuming issuers. We also performed a weather adjustment. This approach is largely compatible with the guidelines given by the Climate Alliance for its member cities (Climate Alliance, 2011).

Results

Considering all these assumptions, the city of Oberhausen emitted 1.95 million metric tons of CO_2 in 2008 This corresponds to per capita emissions of 9 tons, which is below the German average[7]. With respect to the considered time period (1990–2008) energy-related emissions in Germany fell by 21 percent, the emissions in Oberhausen decreased by 28 percent. These figures raise the question whether Oberhausen can be seen as a good-practice example for climate protection.

To explain why emissions decreased so strongly, we need to take a closer look at the data, the emission sources and changes observed according to the above discussed dimensions and their drivers and barriers for urban emissions.

6. processes and procedures involving chemical and mechanical steps to aid in the manufacture of an item or items (e.g. cement production, lime production, adipic acid and nitric acid production, SF6 emissions from electrical equipment etc.). For a more detailed information, please have a closer look at IPCC (2006).

7. According to data forwarded to the UNFCCC, energy-related emissions were 807,42 million metric tons in 2008, which is 9.84 tons per capita tons of CO_2. Data are not completely comparable as the methodological approach is slightly different, e.g. the approach of allocating transport emissions to the city of Oberhausen.

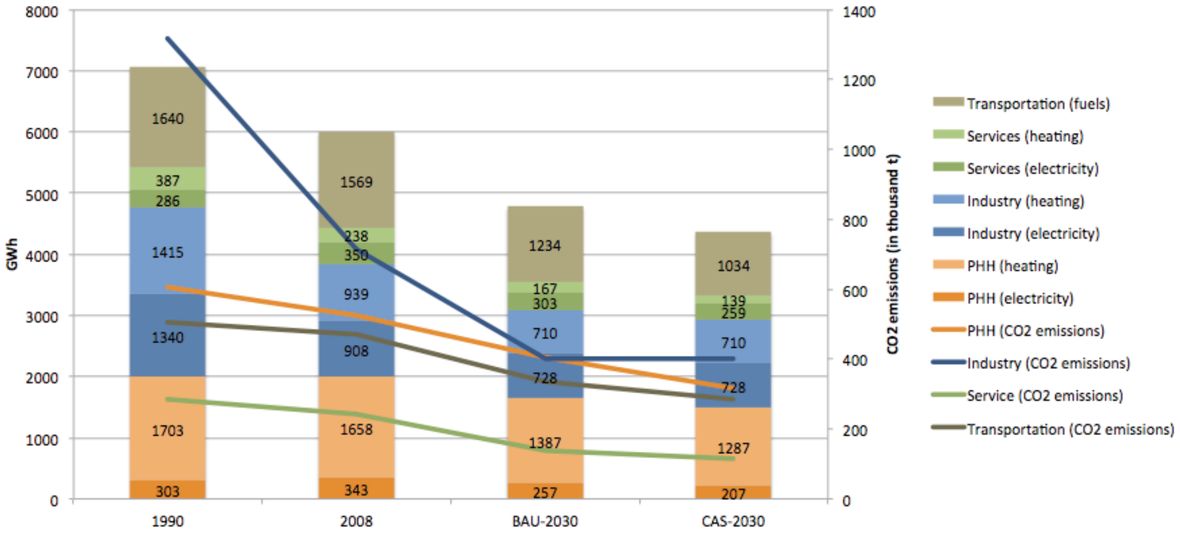

Figure 1. Energy consumption and CO_2 emissions in Oberhausen in 1990, 2008 and 2030. PHH: private households.

Private households

Emissions from private households (i.e. energy use related to heating, cooling, lighting, hot water and all electronic devices) were 526,000 metric tons of CO_2 in 2008. Private households were responsible for 27 percent of the city's total emissions. Compared to 1990, emissions were reduced by 13 percent, which is considerably lower than the city's general emission path. The reasons are manifold, but we focus on two main factors – demographic change and a changed customer demand for living space.

Population in Oberhausen decreased by almost four percent. However, at the same time the number of residential buildings and the amount of living space increased significantly. As a result the per capita living space was 36 square metres in 2008 – 14 percent above the 1990 level. The development of living space with respect to different building types is particularly interesting. While living space for semi-detached houses and multi-family homes increased by only six and eight percent respectively, living space for detached houses rose by 29 percent. The consequences are twofold. First, detached houses require more energy than multi-family homes due to the higher share of outer surface. Second, new housing areas encourage urban sprawl.

The urban district Sterkrade-Nord in the far north of the city is considered as a prestigious living area. This urban district has the lowest unemployment rate in Oberhausen (4.3 percent in 2011), the lowest vacancy rate (e.g. Königshardt (as part of Sterkrade-Nord): 2.2 percent in 2011) (IfS, 2012), a high amount of construction activity and – although rents are comparatively high – the share of accommodation costs on household income is lower than in many other urban districts. Sterkrade-Nord is a typical residential area for families with reasonable incomes. In contrast inner-city areas such as Osterfeld, Oberhausen-Mitte and Alt-Oberhausen struggle with unemployment, vacancies, low rents and an out-dated building stock. At the same time the latter named districts are better connected to the public transport system and are closer to inner-city workplaces and to workplaces in other Ruhr areas cities such as Duisburg, Mühlheim and Essen (LEG, 2012). The city recognized this imbalance and counteracted it by supporting the upgrading of inner-city areas. A first success is already visible: while outskirts showed positive or at least stable populations and inner-city areas shrank for two decades, the trend has reversed in the last years (2006–2010). However, the challenge remains in the future (IfS, 2012).

Higher customer demands for living space, smaller household sizes and other wealth effects are considered to be the main reasons why energy consumption of households has almost stabilized during the last two decades despite energy efficiency improvements. Specific heat demand of residential buildings fell from 241 kWh/m² in 1990 to 213 kWh/m² in 2008, however energy consumption of households at approximately 2 millions MWh in 2008 has remained the same as in 1990. The reason for the decrease in CO_2 emissions as measured, is therefore not a reduction in absolute energy consumption. It is rather due to a substitution of fossil fuels with a high carbon intensity (fuel oil, liquid gas, coal) through less carbon-intense fossil fuels such as natural gas. A second explanation is the modification of power generation capacities in Germany with an uptake of renewable energies and a decrease in the importance of coal-fuelled power plants.

Industry/service sector

The city of Oberhausen has undergone a dramatic structural change in the last decades. This change was accompanied by shrinking processes beginning in the 1960s. The once prosperous city with its economic strength in mining, steel production and processing has since lost population and its former economic basis. The last mine – the "Concordia Zeche" – was closed in 1992 and the last electric steel factory closed its doors in 1997. In the last two decades, the city has strived to develop a new economic profile as a modern site for business and tourism, and thus to diversify its economic basis. This economic reorientation is spearheaded by the so called "Neue Mitte Oberhausen" – a former industrial site that was redesigned into a leisure and shopping centre. However, the project has also been criticized for relocating employment and thus contributing to a loss of importance of the city centre, rather than creating new jobs (Brune and Pump-Uhlmann, 2009).

The structural change is not yet completed. While almost 40 percent of the total work force was employed in the industry sector at the beginning of the 1990s, this figure dropped to less than 20 percent in 2008. Although an equal amount of new jobs was created in the service sector, unemployment still plays a significant role in Oberhausen. Recent data show an unemployment rate of 12.8 percent (2011) which is above the national level. Moreover, the city struggles with high debts. The loss of tax revenue, increasing costs for maintaining social and technical infrastructures and the delegation of tasks from the national to the local level burden Oberhausen just like many other cities in Germany (Junkernheinrich and Micosatt, 2007; DStGB, 2009). Today, Oberhausen is Germany's city with the highest per capita debt (approx. 8,000 Euro per capita), which limits the city's capacity for action in many fields including climate protection (Diehl, 2012; Pagel, 2012).

Despite the structural change, the industry sector still has a significant standing, generating 18 percent of the city's gross value added, and is home to several energy-intensive industry companies, and thus a major driver for urban emissions. In total, the industry/service sector is responsible for almost half of the emissions in Oberhausen. 960,000 metric tons of CO_2 were emitted in 2008 by service and industrial companies. This is a reduction of 40 percent compared to 1990s levels. The major driver was the decrease in CO_2 emissions from industrial sites. Here, emissions declined by 46 percent while emissions of the service sector only fall by 14 percent.

Transportation

The transport sector accounts for 24 percent of total emissions in 2008. Compared to 1990, total transport emissions reduction was four percent. The number of registered vehicles has continuously increased since 1990. Starting from 423 vehicles per 1,000 residents in 1990, this figure rose by 20 percent to 506 vehicles per 1,000 residents in 2007. As a comparison, in Freiburg, a city with comparable population and topography, the same statistical figure is only 417. Although the absolute number of cars in Freiburg has increased as well, this increase corresponds to the population growth.

The data show that the city of Oberhausen did not manage to overcome an urban planning approach prioritizing car use, as it has been common in Germany over the last four to five decades. Even today, new residential and commercial areas are advertised as having good accessibility with private vehicles. As a result, car use continues to be the most important mode of transport in Oberhausen. According to the latest mobility survey in Oberhausen from 2002, 56 percent of all journeys were made through private transport (compared to 32 percent in Freiburg) (Socialdata, 2003). However, the mobility survey also shows progress with respect to public transport use. The share of public transport use increased by 3 percent to 18 percent compared to 1995; current data from the local transport company STOAG indicates a positive development in the future. A further rise in the amount of public transport use may be restricted due to infrastructural constraints. As many cities in the Ruhr area, Oberhausen removed and replaced its tram system by buses after the second world war. Today, Oberhausen once again has one tramway, however to achieve a significant shift from private transport to public transport the tramway network would need a citywide expansion, which may be prevented by the budget deficit of the city.

The share of bicycle use is comparatively low with just 8 percent, especially since geophysical conditions are reasonable for bicycle travel. Oberhausen is located in the "Niederrheinische Tiefebene", and thus the urban area is mainly flat. Moreover, more than 72 percent of all car journeys are shorter than 5 kilometres – a reasonable distance for cycling and walking.

Oberhausen has no airport. However, residents do fly. Therefore we assume an average air travel distance for all residents of Oberhausen. During the last two decades mobility demand has increased causing a near doubling of energy consumption and CO_2 emissions from air travel.

Similar to private cars, the number of lorries registered in Oberhausen rose during the considered time period (plus 37 percent).

The arguments illustrate the existing potentials to reduce emissions from transportation. Even though the measured reduction in passenger and freight transport between 1990 and 2008 can only be explained to a small extent by actions undertaken by the city. Instead it was mainly driven by three external factors. First, vehicles are more efficient than almost 20 years ago. Today, the specific fuel consumption of passenger cars is 20 percent lower than the 1990s level (Rieke, 2002; Kalinowska and Kunert, 2009). Second, a shift to less carbonic diesel fuels occurred in passenger and freight traffic. Third, the national government introduced its Biofuel Quota Law, which obligates the oil industry to ensure that a certain minimum proportion of biofuels for transport purposes is placed on the market.

OBERHAUSEN'S EMISSIONS PATH – HOW COULD IT BE SHAPED IN THE FUTURE?

Building on the GHG inventory, we developed two bottom-up forecast scenarios to show possible futures for the city of Oberhausen. In the business-as-usual scenario (BAU-Scenario) we tried to anticipate main socio-economic developments. The assumptions are either based on forecasts from the statistical department (e.g. population, number of households etc.), local potential analyses or are in line with national scenarios. Here, we primarily refer to two national scenarios. One is a business-as-usual scenario outlined by the WWF (Kirchner and Matthes, 2009). It includes assumptions on the level of equipment in households and business, energy efficiency improvements in all sectors and major economic developments for each branch of the economy. In particular the latter implies that we assume the economic development of each branch in Oberhausen to be similar to the national trend[8]. With respect to the transport sector, we assumed that the mobility patterns of Oberhausens residents will only change due to the demographic developments in the next decades. Vehicle efficiency developments are based on WWF and TREMOD (IFEU, 2010). The development of renewable energies for heat and electricity generation is based on local potential analyses carried out by project partners. In the BAU-Scenario, we expect no further climate actions by the

8. Due to the lack of local data, here we used a very rough approach. We are aware that the development of each of the considered 21 industry and service branches may differ from the national trend. With respect to aforementioned restrictive framework in Oberhausen we thereby may overestimate the economic development and may underestimate the emission reduction potential.

city itself, except those activities that are already implemented. The emission path is therefore a result of the impact of external factors and national policies.

In contrast, the second scenario, the so called climate-action scenario (CAS-Scenario) assumes a high local commitment to boost energy efficiency and climate action in the city. On the basis of potential analyses, stakeholder involvement (e.g. expert interviews, workshops) and in close cooperation with the municipal administration itself, we developed measures and policies to facilitate and accelerate climate actions in the city. These include awareness raising, regulation, financial incentives and advice services and cover all issuers the city expects to gain influence. The selection of appropriate measures and policies also reflects the budget deficit of the city, considering national support programmes as well as local investors. Therefore, the scenario analysis only includes those measures and policies, which the city is capable of implementing. These measures are only a small part of all policies discussed during the project. More detailed information about the methodology, the assumption and the identified measures and policies are presented in Berlo et al. (2012).

In the BAU-Scenario, emissions continue to decrease, amounting to 1.3 million metric tons of CO_2 in 2030, which is 35 percent below the 2008 level. In the CAS-Scenario, emissions are 1.1 million metric tons of CO_2 in 2030, which is a further 8.5 percent lower than in the BAU-Scenario. Compared to 1990, the reduction of the CAS-Scenario amounts to 59 percent. The scenarios show that Oberhausen has a good chance to achieve its target to halve emissions by 2030 compared to 1990. If the city's emissions decrease at the same rate until 2050, Oberhausen will be a low-carbon city by then. A more detailed look at the emission sectors, theirs paths and the differences between the BAU- and CAS-Scenario reveals a more differentiated picture. The largest absolute emission reduction is expected to occur in the industry sector (45 percent or 327,000 tons of CO_2 until 2030 compared to 2008 for both scenarios). Low economic growth, energy efficiency improvements and a further decline of energy-intensive employment are the main drivers. This means that the city of Oberhausen owes its past and future emission path to a significant amount to an emission sector which can hardly be influenced by the city's activity.

With respect to private households and the transport sector, the situation differs. Policies for providing energy advice and financial incentives help to lower barriers for energy retrofit. Quantity and quality of energy retrofit increases gradually over time and the market diffusion of energy efficient technical equipment and appliances is accelerated. In the transport sector, a modal shift from car use to public transport, walking and cycling is expected. The share of non-car transport increases from 44 percent (2008) to 56 percent in 2030 in the CAS-Scenario.

Conclusion and lessons learned

The analyses of the historical emission path of Oberhausen and the scenarios carried out for the future development show that emissions have decreased until now and will further decrease. The city of Oberhausen is moving on a low-carbon path. However, the analyses also show that drivers to reduce CO_2 emissions can only be addressed to a small extent by local policies. In contrast, barriers that are typical for shrinking cities, exist. The vicious circle of debts, shrinking population, staff reduction, loss of image etc. restricts local capacity for action. Our analyses show that both, drivers and barriers, significantly affect Oberhausen's emissions. We cannot say whether the set target is ambitious or not for the city of Oberhausen, but it becomes obvious that there is a need to rethink and to adjust current practice of target formulation for shrinking and growing cities alike in the following fields:

POLITICAL TARGET LEVEL

- **Adjust the target to the framework conditions of a city** – The case of Oberhausen shows that urban development is subject to several framework conditions which may serve as drivers or barriers for a low-carbon transition. Most of these conditions can usually only be changed in the long run, which is why there is a path dependency of cities that has to be considered in formulating climate protection targets. Cities differ with regard to their current emission level as well as their historical and future emission paths. Research is needed to identify those cities with a higher potential for reducing their emissions. It seems obvious that a mere adoption of (inter)nationally formulated targets is inappropriate due to the diversity of cities.
- **Define realistic political targets** – Cities need ambitious political targets. However, they have to be adjusted to the existing framework conditions, otherwise there is a high risk of failure which lowers the credibility of local policies and policy-making.
- **Define milestones and roadmaps instead of a mere long-term CO_2 reduction goal** – So far, cities normally commit to a long-term target (e.g. 2030 or 2050). Yet, there is urgent need to define roadmaps and milestones to achieve this target. It is the only way to evaluate the effectiveness of policy-making. A roadmap should also include sub-targets in the fields of energy efficiency, renewable energies and for the mobility sector.
- **Make political targets tangible and develop visions** – Currently, climate protection has a high priority in many cities. However, especially at the local level, urban planning should focus on sustainable development rather than on a low-carbon path development. Both developments need visions of how leisure, work life, mobility etc. should look in the future. Although several issues are better addressed through national policies (e.g. energy performance standards for appliances or for buildings etc.), many policies have to be implemented and enforced by residents in the city. The local level benefits from its proximity to its residents. It is the only political level where political decisions and their impact are spatially linked. Therefore it is crucial to create a common understanding for their need.
- **Find alternatives for relative reduction targets** – So far, most cities have committed to a relative reduction target. This entails two problems. First, GHG inventories are rather new instruments for many cities and thus data is missing to measure emissions emitted in the past. Second, the future socio-economic development of a city determines how

Table 1. Past and potential future impact of dimensions and their features on the emissions level of the three sectors in Oberhausen.

Dimension		Situation in Oberhausen: Past (1990-2008)	Situation in Oberhausen: Future (2008-2030)	Most likely impact on CO_2 emissions: Past (1990-2008): Transport	Past: Private Households	Past: Industry and service sector	Future (2008-2030): Transport	Future: Private Households	Future: Industry and Service sector
Geophysical	Location	mainly flat urban area		↘	–	–	↘	–	–
Geophysical	Climate Conditions	moderate climate, less heating degree days than in more continental shaped cities in Germany, average rain conditions, climate change impact leads to less heating degree days, but more cooling degree days			↘	↘		↘	↘
Spatial	Urban Planning	increasing number of registered cars and lorries and constant high level of car use		↗	–	–	↗	–	–
Spatial	Urban Planning	growing settlement and traffic areas, longer supply routes, rather low level of mixed use	better compact city developments	↗	↗	–	↘	↘	–
Built environment and Infrastructure	Buildings Stock and Real estate market	low rents, increasing vacancies in shrinking districts	rents remain on a low level, danger of increasing vacancies	–	↗	–	–	↗	–
Built environment and Infrastructure	Buildings Stock and Real estate market	investor-user dilemma due to low level of building ownership		–	↗	–	–	↗	–
Built environment and Infrastructure	energy infrastructure	high share of district heating, low specific emission level of existing thermal power stations due to industrial waste heat and renewables with a minor share of fossil fuels	expansion of district heating, increasing share of renewable energy sources	–	↘	↘	–	↘	↘
Built environment and Infrastructure	Transport infrastructure	increase of public transport use, enhancing quality and quantity of public transport service	innovation in public transport (electric trolley buses, increasing quality	↘	–	–	↘	–	–
Built environment and Infrastructure	Transport infrastructure	lack of high-quality walking/cycling infrastructure, car-friendly city	increasing share of walking and cycling lanes	↗	–	–	↘	–	–
Social	Population and demography	decreasing population	decreasing population	↘	↘	–	↘	↘	–
Social	Population and demography	ageing population	ageing population	↘	↗	–	↘	↗	–
Social	Lifestyle	decreasing household size, rather low but increasing living space per capita		–	↗	–	–	↗	–
Social	Lifestyle	increasing use of electronic devices in households and companies		–	↗	↗	–	↗	↗
Service/Industry	Economic Structure	decreasing importance of energy-intensive industries (still remain a significant issuer), migration of energy-intensive production, growing service-oriented economy	further decrease of energy-intensive industries,	–	–	↘	–	–	↘
Service/Industry	Economic development	moderate but steady GDP growth	economic contraction due to the economic crisis (2008/09) for the first years of the scenarios, afterwards morderate but steady GDP growth	↗	↗	↗	↗	↗	↗
Climate Governance	Local Commitment and Targets	member of climate alliance, local climate action plan	increasing importance of climate-related issues in city covernment decisions	↘	↘	↘	↘	↘	↘
Climate Governance	National Policies	policies to enhance energy efficiency of vehicles, appliances, buildings, production and to uptake renewable energies and cogeneration	policies expected to be expanded	↘	↘	↘	↘	↘	↘

↗ Increase in emissions; ↘ decrease in emissions; – no impact or impact cannot be assessed.

ambitious the target is. Set targets of shrinking cities are less ambitious compared to those of growing cities as per-capita emissions in shrinking cities do not have to decrease as much relative to the number of residents as for prosperous and growing cities. Two alternatives may be considered. A city may commit to a per capita target or to an absolute reduction target.

TARGETS AND THEIR MEASUREMENT

- **Collect data to develop an additional target based on consumption pattern of the city** – So far, urban GHG emissions are based on the local production of goods and services. Except for the import of electricity, GHG inventories measure emissions within the geographic boundaries of a city. Yet with increasing globalization, international trade is growing and so are international interdependencies. Energy-intensive manufacturing has almost completely left urban areas and has mainly moved from urban areas in developed countries to developing countries. But the produced goods are still consumed in cities in the developed world. Many cities in developed countries benefit from this economic transformation and the shift of production capacities. For a fair and globally accepted measurement of local GHG emissions the current methodologies have to be adjusted. They should not only measure the production-based emissions, but also take into account the emissions caused by the consumption of goods and services in the city.

LOCAL TARGETS AND MULTI-LEVEL-GOVERNANCE

- **Local targets require a supportive national framework** – Cities are expected to play a key role in mitigating climate change. However, this expectation overestimates their capacity to act. Cities do not have full control over their emissions sources (e.g. electricity generation from out-of-boundary areas). Moreover, several fields of action can be better addressed through national policies. Energy efficiency standards for appliances and buildings or efficiency standards for vehicles can be implemented more easily and more effectively by national governments. Local commitment to mitigate climate change therefore requires a supportive national framework.
- **Networks have to be strengthened** – To further accelerate the exchange of best-practices between cities and the standardization of methodologies, especially in the case of smaller cities, networks have to be strengthened. Furthermore, the activities and experiences of cities should be fed back to supranational level (e.g. EU) to improve legislation.
- **Vertical integration of national and local targets** – National targets do not take into account the strengths, assets and barriers of individual cities. Therefore they may not be in line with locally existing development strategies. Moreover, there is also only limited integration and coordination of activities on different political levels, which may result in ineffective policies.

TARGETS AND LOCAL ACTION

- **Targets and the non-effectiveness of local actions on certain issuers** – The city's influence over different issuers varies. While urban planning may help to reduce urban transport or public utility companies may change or extend their product portfolio to support energy efficiency, other sectors or issuers are less influenceable. The business strategy of a company or its decision for a location, in particular for nationally and internationally operating companies, are out of the sphere of the city's influence.
- **Long-term targets and strategic urban planning decisions** – Urban planning decisions and urban planning visions can only be adjusted over long time periods. Urban planning approaches that prioritize car-use and monofunctional urban districts, as can be observed in many American, Asian-pacific and European cities, negatively affects emissions from the building and transportation sector. It also causes higher costs for urban infrastructures such as water or wastewater supply networks.

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